Report as of FY2009 for 2008VI112B: "Use of Wetland Plants to Manage Nitrate Levels in a Biofloc Fish Production System"

Publications

- Other Publications:
    - No publications have resulted as yet from this project.

Report Follows

PROBLEM AND RESEARCH OBJECTIVES

Maximizing the use of freshwater resources and output from production systems is critical for the future success of agricultural enterprises in the U.S. Virgin Islands. The average rainfall in the region can vary from 400 to 1300 millimeters per year and is concentrated in the wet season (September to November). The U.S. Virgin Islands have only intermittent seasonal streams and freshwater impoundments that frequently dry through evaporation and seepage. Farmers rely on wells or haul water to their field plots for irrigation.

Dual use of the freshwater resource can be achieved by first culturing fish and then applying fish effluent to agronomic crops as irrigation water. The University of the Virgin Islands has developed a commercial biofloc system for the production of tilapia but nitrate-nitrogen accumulates in the system as part of the biological treatment processes. Reducing nitrates to a level where they do not impact fish production nor become a source of groundwater pollution (if applied extensively to agronomic crops) is a desire of farmers incorporating an aquaculture component into their farm enterprise.

The research will determine which of nine wetland plants is best suited for removing nitrate-nitrogen from aquaculture water circulated through denitrification raceways. Reducing nitrate levels to less than 100 mg/l will allow the water to be used extensively on agronomic crops. Farmers will be able to incorporate aquaculture into their farm enterprise and produce additional crops of value. These could include flowers or foliage for sale to florists or a marketable wetland plant for sale to developers mitigating land damage. The results of this study will allow producers to maximize use of their production system without the need to perform undesirable water exchanges to improve water quality

The research will evaluate nine littoral, bog or wetland plants for their growth, production and nitrate removal efficiency in the UVI Aquaculture Program biofloc system denitrifying raceways. The U.S. Virgin Islands have few native freshwater wetland plants due to previous agricultural practices, development and lack of natural freshwater resources. Three have been identified, *Sesuvium portalacastrum*, sea purslane, *Pluchea odorata*, fleabane and *Thalia geniculata*, bent alligator flag (Acevedo-Rodriguez, 2005). These will be cultivated because of their market potential to developers that are required to mitigate wetland damage caused by construction activities. Six other plants have been identified for their use by florists, either for flowers or foliage.

METHODOLOGY

Wetland plants, native and introduced species, will be planted into the denitrification raceways and allowed to establish in blocked areas. The biofloc system will be operated for a six-month period as a fish production trail with daily management including feeding, aeration, sludge removal and pH adjustment. Water quality and plant tissue will be analyzed periodically throughout the fish production trial. Data analysis will determine the absolute decrease in nitrate-nitrogen over the length of the raceways and the rate of nitrate-nitrogen accumulation in the system over the production period.

After the production trial, the fish will be held in the rearing tank and the system managed as a pre-sale holding facility before the fish are marketed. The denitrification raceways will be planted with two species of wetland plant, one species in each raceway. Water quality data analysis will determine the rate of nitrate-nitrogen accumulation and the absolute decrease in nitrate-nitrogen over the length of the raceways. Data on the growth, production and harvest of marketable plant products will be collected and analyzed. An economic analysis of each plant specie will be made to determine the best plant for inclusion in the biofloc system.

PRINCIPAL FINDINGS AND SIGNIFICANCE

TRIAL #1

The biofloc aquaculture system is being used for this research which evaluates the production potential of several wetland plants in raceways using the culture water. The 200-m^3 circular tank was stocked with 5,000 153-g tilapia fingerlings on September 3, 2008. The system also has a 2-m^3 clarifier for removal of fecal solids and other settleable solids, a base addition tank, and 2 raceways for denitrification of the water. Water is pumped through these units with a 1/20th hp circulating pump. The tank water was continuously circulated horizontally with one ¾ hp prop aerator and was aerated with up to 3 vertical aerators.

The fish were reared for 168 days (24 weeks) at which time they were harvested. Final production was 3,711 kgs or 18.55 kg/m^3. During the production period the fish were fed twice each day to apparent satiation for 30 minutes. Digestion and metabolism produce feces and ammonia, NH_3^+. The feces were removed by the clarifier and the raceways. The ammonia was removed by biological processes of nitrifying bacteria in the water column. The end product of nitrification, nitrate-nitrogen (NO_3-N) accumulated in the water. Feces and solids that accumulate in the raceways form anaerobic zones where denitrifying bacteria thrive and can convert nitrate to nitrogen gas. (Figure 1.)

Nine varieties of wetland plants were randomly planted in each raceway. Each variety was planted in a quadrent of 2-m^2 at a density of 4/m^2. These plants were allowed to grow, without tending, by their natural propagation pattern. The two cana lily varieties did not survive. Not all of the other varieties thrived. *Colocasia esculenta*, Green Taro or Dasheen, grew well and produced many plantlets. Final yield was 33.32 kg/m^2. *Cyperus papyrus*, Egyptian papyrus, was the next most productive variety but yielded only half as much plant mass, 16.02 kg/m^2. (Table 1.)

TRIAL #2

In the second phase of this research taro, *C. esculenta*, was planted in one raceway at a density of $4/m^2$ and allowed to grow for 4 months. Dissolved oxygen, pH, ammonia-nitrogen and nitrate-nitrogen water quality parameters were monitored by standard methods biweekly in the rearing tank and at the effluent ends of each raceway. Water quality was also monitored in one raceway with a YSI Multiparameter water quality sonde for a period of three weeks. The sonde recorded hourly pH, ammonium and nitrate values. A UVI student worker was assigned to the maintenance and monitoring of this equipment.

Fourteen (14) plots of 2-m2 each were marked along one trough. Each plot was planted with 8 taro plantlets, (mean wt., 358 g). Over the course of the production period the plants in the first 2 plots died. A gradient of successful growth continued down the trough from plot 3 to 14. Production data for each plot is presented in Table 2.

The influent end of the denitrifying raceway becomes heavily settled with solid waste from the fish production tank. Anaerobic conditions that are desired and encouraged for nitrate removal also produce undesirable byproducts including methane and hydrogen sulfide gas. These byproducts were not measured in this research but it is speculated that they had a detrimental effect on the taro planted in the influent area. Further along the trough solids continued to accumulate did not entrap the roots and corms of the plants.

Nitrate levels in the fish production tank need to be maintained below 500 mg/l for optimum production. This is achieved by the anaerobic conditions in the raceway (Figure 2). Continuous removal of nitrate through the denitrification process dilutes the nitrate-nitrogen level in the rearing tank.

Taro can also remove nitrate by direct uptake through the roots and incorporation into the plant material. Samples of plant material were taken and the tissue analyzed. Nitrogen made up 4.92% of the dry weight of the plant and was typical for herbaceous perennial plants.

The production of edible corms is an additional valuable resource for a farmer. The number of corms increased along the length of the trough (Table 2). The production period for edible corms was not reached so most of the corms were immature and non-marketable. The number of plants that had propagated from the original planting is another indication of potential corm production. Taro corm production can be 9-12 months and is longer than the production period for the tilapia in the rearing tank. This presents production scheduling challenges for farmers integrating tilapia and taro production.

The benefit of anaerobic denitrifying raceways is the removal of nitrate without the need for dilutions with large volumes of water. The raceway appears to have value for the production of a plant crop but several constraints make integration impractical.

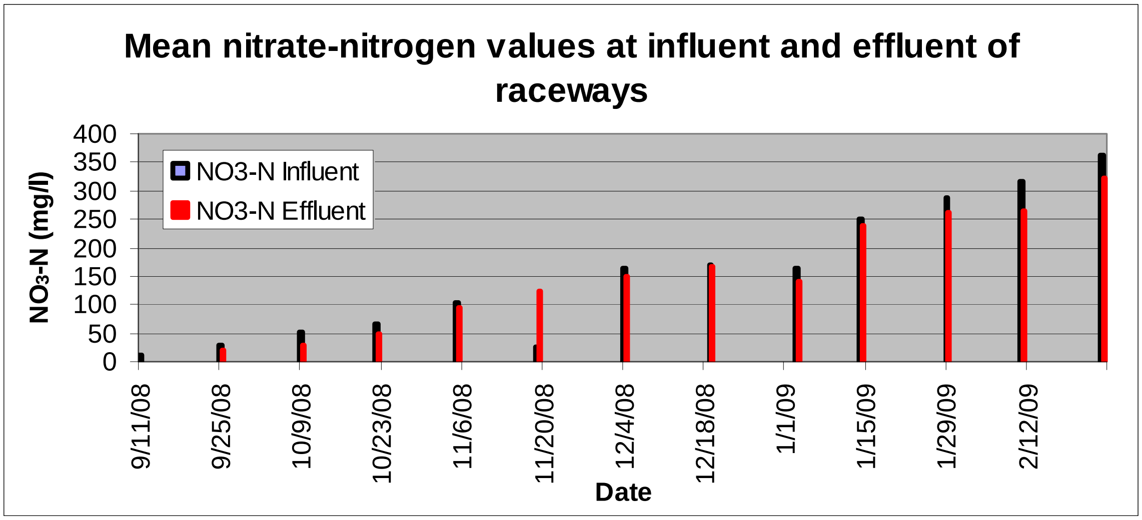

Figure 1. Mean nitrate-nitrogen values show a decline in values from the denitrification occurring in the raceways between the influent and effluent ends.

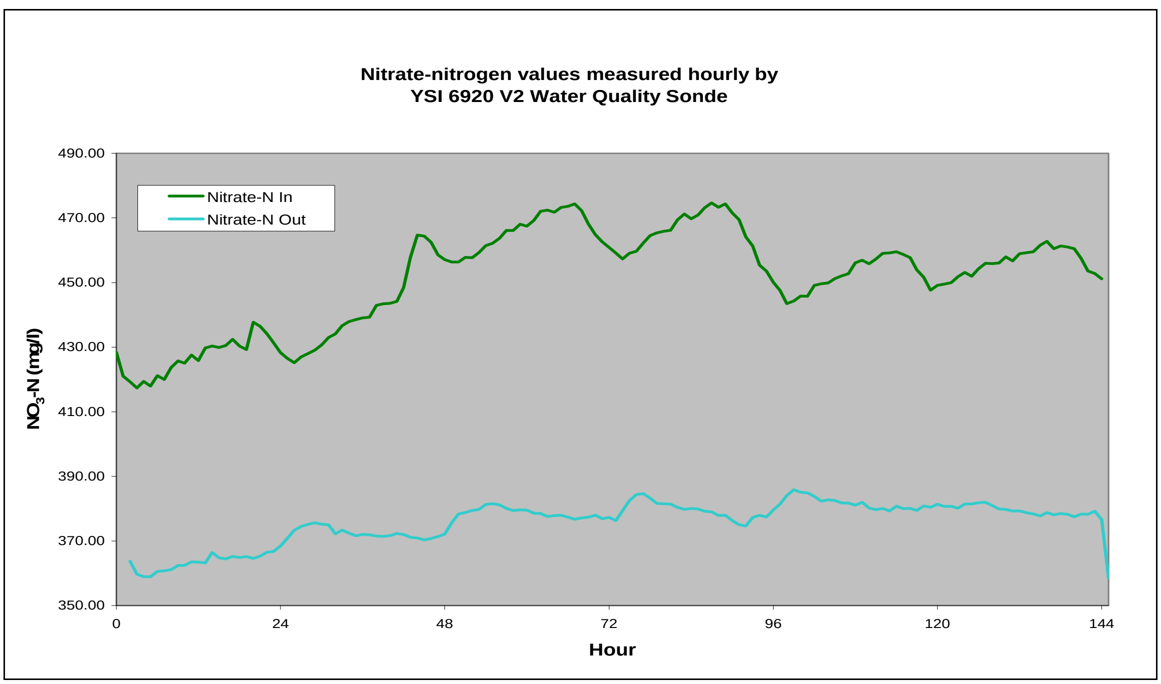

Figure 2. Typical trend of nitrate-nitrogen level of influent and effluent in denitrifying trough used for taro production.

Table 1. Wetland plants grown in denitrifying raceways show a wide range of production.

Latin Name	Common Name	Raceway 1	Raceway 2	Mean kg/m^3
C. esculenta	Green Taro (dasheen)	32.86	33.66	33.26
C. papyrus	Papyrus	18.67	13.361	16.02
S. lancifolia	Giant Sagittaria	6.926	6.034	6.48
I. versicolor	Iris	0.277	0.817	0.55
H. caribaea variegata	Verigated spider lily	0.224	0.338	0.28
C. americanum	Bog lily	0.187	0.162	0.17
T. geniculata	Bent aligator flag	0	1.579	0.79

Table 2.

Position*	Initial Biomass (kgs)	Final Biomass (kgs)	Gain (kgs)	Corms (count)	Corms (kgs)	Corms (mean)	Plant Height (cm)	Plant Count (ea)
1								
2								
3	1.42	0.26	-1.16	9	0.22	0.024	**	**
4	2.65	0.44	-2.21	11	0.38	0.035	**	**
5	2.92	0.60	-2.32	2	0.3	0.150	**	**
6	2.96	1.24	-1.72	4	0.54	0.135	20.17	6
7	3.1	3.84	0.74	5	0.74	0.148	35.75	24
8	2.82	7.98	5.16	31	1.46	0.047	44.78	37
9	2.74	7.48	4.74	16	0.86	0.054	42.42	45
10	4.36	14.30	9.94	49	1.94	0.040	54.93	92
11	3.28	8.40	5.12	24	1.44	0.060	57.87	47
12	1.72	10.04	8.32	53	1.22	0.023	55.94	68
13	3.18	13.20	10.02	66	1.58	0.024	54.57	89
14	3.26	7.52	4.26	84	1.28	0.015	36.01	97

*plants in positions 1-2 had no remaining plant material.

**plants in positions 3-5 had only corms and no vegetative plant material.